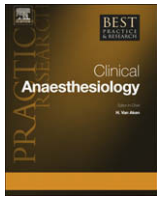
Best Practice & Research Clinical Anaesthesiology 23 (2009) 81–93

Contents lists available at ScienceDirect

Best Practice & Research Clinical Anaesthesiology

journal homepage: www.elsevier.com/locate/bean



7

Advanced closed loops during mechanical ventilation (PAV, NAVA, ASV, SmartCare)

François Lellouche, MD, PhD, Doctor [a,*], Laurent Brochard, MD, Professor [b]

[a] Institut Universitaire de Cardiologie et de Pneumologie de l'Hôpital Laval, Centre de Recherche de l'Hôpital Laval, 2725, chemin Sainte-Foy, G1V4G5, Québec, QC, Canada
[b] Service de Réanimation Médicale, Hôpital Henri Mondor, 51, Avenue du Maréchal de Lattre de Tassigny, 94010 Créteil, France

Keywords:
proportional assist ventilation
neurally adjusted ventilatory assist
SmartCare
adaptive support ventilation
closed-loop systems
mechanical ventilation
weaning
patient–ventilator interactions
knowledge transfer
new modes

New modes of mechanical ventilation with advanced closed loops are now available, and in the future these could assume a greater role in supporting critically ill patients in intensive care units (ICUs) for several reasons. Two modes of ventilation – proportional assist ventilation and neurally adjusted ventilatory assist – deliver assisted ventilation proportional to the patient's effort, improving patient–ventilator synchrony. Also, a few systems that automate the medical reasoning with advanced closed-loops, such as SmartCare and adaptive support ventilation, have the potential to improve knowledge transfer by continuously implementing automated protocols. Moreover, they may improve patient–ventilator interactions and outcomes, and provide a partial solution to the forecast clinician shortages by reducing ICU-related costs, time spent on mechanical ventilation, and staff workload. Preliminary studies are promising, and initial systems are currently being refined with increasing clinical experience. A new era of mechanical ventilation should emerge with these systems.

All the ventilatory modes currently used during mechanical ventilation function with closed loops.[1] Even a 'simple' mode such as pressure support ventilation uses rules to initiate the pressurization, to determine the pressurization slope, to end the pressurization, to regulate the flow within the cycle, and to open the expiratory valve. These rules work in a closed loop based on airway pressure and flow signals.[2] The field of mechanical ventilation is currently moving towards the development of new ventilation modalities and new tools to monitor and manage patients requiring mechanical ventilation.

* Corresponding author. Tel.: +1 418 656 87 11x3298.
E-mail address: francois.lellouche@crhl.ulaval.ca (F. Lellouche).

1521-6896/$ – see front matter © 2008 Elsevier Ltd. All rights reserved.
doi:10.1016/j.bpa.2008.08.001

Thanks to the technological advances in computing and in the field of artificial intelligence, some 'intelligent modes' with complex closed loops have been developed.[3] We will discuss why we should integrate these new modalities into clinical practice in the future. We will also review these new modalities of ventilation using more complex closed loops and integrating physiological principles, such as 'proportional assist ventilation' (PAV), 'neurally adjusted ventilatory assist' (NAVA), or the 'adaptive support ventilation' (ASV), or reproducing clinical reasoning as does the SmartCare™ system.

Many new modes have emerged since the early 1990s, but few have demonstrated a real benefit for patients[4], and some may even be deleterious.[5–7] We present here some new modes of ventilation that we feel seem to be real technological innovations with a strong physiological background, and not simply new modes in addition to the long existing list. Some of these systems have shown a real clinical benefit, and others have the potential to do so, especially during the weaning of mechanical ventilation, but as yet these have been very little evaluated. These new modes of ventilation use closed loops with variable levels of complexity.[1] The modes of PAV[8,9] and NAVA[10] can deliver ventilation proportional to the instantaneous patient effort and seem to improve patient–ventilator interaction.[11] The ASV[12] might be of interest in weaning from mechanical ventilation, as may the system NeoGanesh (commercially available under the name of SmartCare™)[13] for which the first clinical evaluations are promising.[14,15] The common characteristic of these new modalities of ventilation is their adaptation to the patient, which explains the improvement in patient–ventilator interaction. Each of these modes will change the level of assistance in response to the patient's breathing pattern, but with response times that depend on the type of closed loop used. Nevertheless, and despite their attractiveness, all these new methods of ventilation must demonstrate their clinical benefits before being recommended and used in routine practice.[4] Also, it is of the utmost importance to avoid the pitfall of choosing an attractive new mode with little available evaluation when 'old' modes which are better known and well evaluated – such as pressure support ventilation[2], assist control ventilation[16], or pressure-controlled ventilation – can be used in most clinical situations.

Need for automation of mechanical ventilation

Why automated mechanical ventilation will be used in the future

There are now strong reasons to believe that automated mechanical ventilation will be used more and more in the future. It has been clearly shown that the patient's outcome in the ICU is directly linked to the staff workload.[17–21] A marked increase in the use of mechanical ventilation is forecast[22–24], concurrent with a stagnation in the number of clinicians skilled in taking care of these patients (mainly intensivists, anaesthesiologists, pneumologists, and respiratory therapists).[22] Indeed, Needham et al made the projection that in the next 15 years the number of patients requiring mechanical ventilation in Ontario will increase by 80% in comparison with the year 2000.[23] This projection is explained on the one hand by the demographic characteristics in the developing country and the increasing proportion of elderly people in the population ('baby boom')[23], and on the other hand by an increase in the mean duration of mechanical ventilation.[25] These projections have been confirmed in a recently published study.[24] In this study, the projections for 2020 show that the number of prolonged mechanical ventilations (>96 hours) will be more than doubled compared to the number in year 2000. Also, the population undergoing prolonged mechanical ventilation represents one third of the adults on mechanical ventilation, and consumes two thirds of the hospital resources. Indeed, it has been recently demonstrated that the cost of mechanical ventilation is particularly high[26,27], and it is recommended that research be focused on a reduction in the duration of mechanical ventilation.[27,28]

Angus et al had forecast that the shortage of clinicians to take care of patients on mechanical ventilation would begin in 2007 and would worsen progressively thereafter.[22] This situation is happening while *the ICUs are already under stress,* with (1) a growing number of medical errors being described in the literature[29–32] related to the workload and to the shortage of personnel[33–37]; and (2) the recent description of a high frequency of severe 'burnout syndrome' among physicians[38,39] and nurses[40,41] working in ICUs. In the study by Donchin et al, the average number of activities per patient per day was 178, and the authors reported an estimated mean number of 1.7 errors per patient per day. Among the activities, those related to breathing were the most frequent (26% of all activities), and